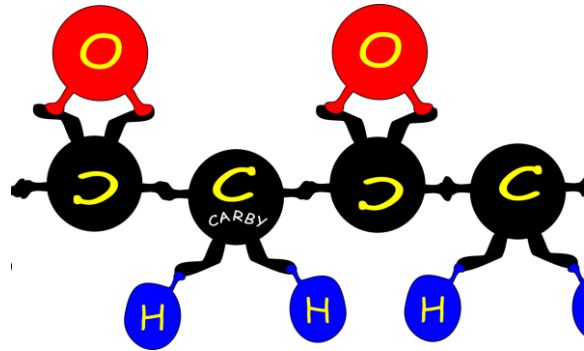


A carbon atom's life story

Hi.

My name's Carby - I'm a carbon atom. Actually, I'm the one just below your fingernail in the cuticle of your pinky - 4,113,275,021,772 from (look hard). I'm part of a collagen molecule, means I'm joined together with a lot of my carbon atoms. We're a happy molecule - all my carbons, plus a lot of hydrogen atoms, some and nitrogen atoms and a few other types as well. We're all holding hands to make a giant molecule - one big happy family.



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I'm going to tell you my story.

I was born about 8 billion years ago (I don't know the exact number, it sort of gets hard to keep track after the first billion) in a star about thousands of light years away. Don't go looking for it - you won't find it. It's gone, it blew up. That's how I got here. Perhaps I'd better explain.

My birth star was quite a big one (I don't mean to brag, size isn't everything), about 12 times the size of the Sun. Like all stars, it was made mostly of hydrogen. Deep down inside the star, the heat and pressure was enough to squeeze the hydrogen atoms together to make helium atoms - my parents. They floated around quite happily for millions of years. But because they were denser than hydrogen, they eventually sank down to the core, where it's nice and hot. The helium that sank down to the middle and just got hotter and hotter, while in a shell around the helium the hydrogen kept fusing together and producing the energy to make star shine.



Eventually the temperature at the star's core got hot enough for helium fusion. When this happens, three helium atoms would join together to make one carbon atom. That's how I was born. But WOW - that makes a LOT of heat! The extra heat from this process made the star swell up to over a hundred times its original size. Strangely, this made the outside of the star cooler, so it went down from white hot to red hot. The star became something called a red giant. Our local Sun

will eventually do the same thing, but don't worry, it's not going to happen for about another six billion years. That's plenty of time to make plans.

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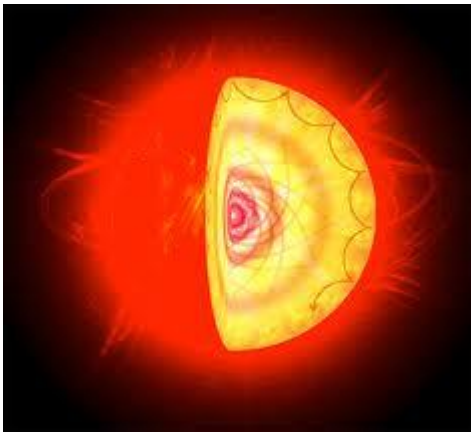
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Because my birth star was so much bigger than the Sun, this fusion process didn't stop there. Quite a few of my brother carbons sank to the core, where they fused again to make oxygen, then the fusion process continued to produce neon and a other heavier elements (I managed to avoid this; I was joy

riding on the convection currents outside the core). Eventually, iron was produced at the core. It stopped there. You see, us light elements give off energy when we join together by fusion to make a heavier element. That only works until you get to iron. To make atoms that are heavier than iron you have to *put energy in* - a lot of energy. So the iron atoms just sank to the core and waited there. They couldn't produce any more heat because they couldn't fuse together.

For a smaller star, that would be the end of it. The process would go on until nearly all the star had turned into the heaviest element it could, and the star would just be a big ball of VERY HOT atoms. Stars like this are called 'white dwarfs' (they're white hot to start with, but eventually cool down into black dwarfs). There's one of these stars in the Sirius system - you can find Sirius easily, it's the brightest star in the sky, near Orion (you know, the constellation with the three stars in a row). You won't see the white dwarf though, because it's too small to see without a very, very powerful telescope. We can tell it's there because it's so heavy it makes Sirius 'wobble' as it orbits because of its gravity. Our Sun will eventually become a white dwarf. It will be quite small and probably made mostly of silicon and oxygen.

My birth star was a lot bigger than Sirius (either of the two stars) or the Sun. This was important. Because it was so big, it built up iron in its core. Eventually there 1.4 times the mass of the Sun worth



of iron was sitting there at the core. That's an important number. When there is this much iron, the gravity is so powerful the electrons in the atoms are pushed into the protons to make neutrons. This happens very suddenly, and causes the core of the star to collapse, releasing a HUGE amount of heat:



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This heat blew off almost all the remaining parts of my birth star - hydrogen, helium and other atoms. Including me - I was still playing around in the convection currents when BANG - I was thrown out into space by the explosion (they call it a *supernova*; a bang like that has to be super-sized for sure).

I travelled several light years out into space, together with lots of my fellow atoms. Some of them were fused by the huge heat to make really heavy elements - like gold, uranium, tungsten and so on. If you find these elements anywhere, you know there's been a supernova. It's the only thing hot enough to make them.

We spent quite a long time drifting around in space as what is called a Giant Molecular Cloud (GMC). Sometimes, radiation made us glow and we looked really pretty, and we became a *nebula*. You can see a nebula like my old one in Orion's belt if you use a pair of binoculars; look for a reddish glowing cloud. It's called the Orion Nebula (hey, astronomers are really imaginative with names - not).



My GMC time didn't last forever though. Shockwaves, from another supernova, stirred us up into whirls and eddies. The places where the gases were a bit denser had more gravity, and pulled more gas into them. The gases clumped together into bigger and bigger whirls, which contracted because of their gravity.



This went on until some of the clumps got hot enough to turn new stars. This happened all the GMC - for a while, we were 'star nursery'. Have look at Matariki (the Pleiades). That's



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another stellar nursery, where forty or fifty stars are being born.

I wasn't part of the new star (the Sun) though. I was in a disc of gas around the new star (it's disc-shaped because the centrifugal force of the spin cancels out the gravity in the direction of the spin). When the Sun 'ignited' - that is, when fusion started - there was a big 'flash' of heat. This blew a lot of the hydrogen and helium and other light stuff from closer to the Sun out into the outer part of the disc, leaving behind heavier stuff like iron, silicon, oxygen and so on. I was hanging around with some oxygens at the time as carbon dioxide, so I managed to stay in the inner part of the disc.

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The Sun settled down into a star quite quickly. During this time, it was flung out of the stellar nursery and started to orbit the galaxy in its own orbit, so none of the Sun's old nursery mates are nearby any more. The disc around the Sun went with it. This disc was a *mess*. All the stuff cooled down into a lot of rocks and big gassy balls and so on which kept colliding, breaking up, and colliding again (geologists call this time the 'Hadean', after Hades or Hell). Over time, though, the bigger lumps started to stabilise as they had more gravity and stuff tended to stick to them, making them bigger still. A few tens of millions went by, and most of the lumps got bigger and bigger until they became planets.



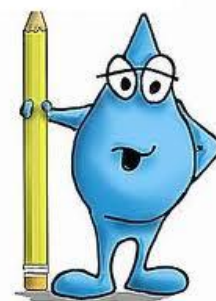
I was stuck on the third rock from the Sun, called Earth. It wasn't a very promising planet, and almost came to grief quite early on. You see, we were just settling down into a nice round ball with a methane and carbon dioxide atmosphere when BAM! Another planet, called Theia, smacked right into us. This might have been a disaster, but turned out to be the best thing that ever happened to us. You see, instead of breaking up the Earth altogether, Theia merged with Earth (most of it is still there in the mantle). However, it also sent a lot of rocky stuff into orbit. This rocky stuff gradually stuck together to make the Moon. The Moon's gravity stabilised the Earth's rotation and stopped it flip-flopping all over the place. Also, the Moon caused tides which would be hugely important later on in setting the scene for life to appear.



Earth was a hellish place at this time - red hot, full of volcanoes, constantly hit by comets and so on. The comets were a blessing in disguise, though. Many of them were made mostly of water. As the Earth cooled down, some of the water started to condense out as rain. It rained continuously for millions of years, but eventually oceans started to build up. All that rain dissolved lots of minerals from the rocks, so the oceans were full of these and things like ammonia and salts and so on. Somehow, in this time, something strange happened. Zillions of chemical reactions took place in this water and in the

atmosphere (there was almost continuous lightning, which made some chemicals called amino acids) and something new appeared: chemicals with the ability to make copies of themselves - LIFE. I don't know exactly how it happened, though. I was hooked up with these hydrogen dudes at the time, bumming round the atmosphere as a methane molecule.

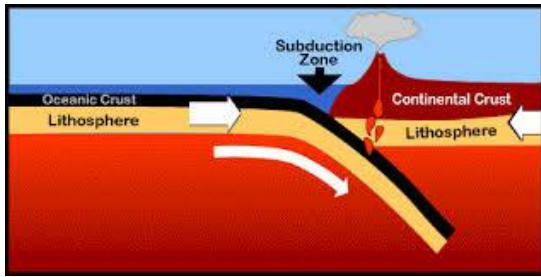
Actually, once life started nothing much happened that worried me for a long while. But after about a billion years, I started to notice more and more of these scary oxygen molecules in the atmosphere. What had happened is that, down there in the oceans, life had evolved and hit on a new trick for storing energy from sunlight. This involved taking the carbon from carbon dioxide and joining it up with water molecules to make sugars. It gave off oxygen as a waste product. These oxygen molecules would attack methane molecules, like I was at the time, to produce carbon dioxide and water. I knew my days as part of a methane molecule were numbered.



Sure enough, one day two oxygen molecules attacked me. One of them took off with my hydrogens and made two water molecules. The other one grabbed me. It was a bit brutal, but these things happen. I got over it and started to enjoy life as a carbon dioxide molecule. Not for long, though.

What I didn't know is that this was going to lead to a big change in lifestyle. You see, carbon dioxide is much more soluble in water than methane. I found myself in a raindrop, hooked up with these water molecules as carbonic acid. And it didn't stop there. Once I fell to the ground, the acid reacted with some basalt rock. I found myself making my way to the sea as part of a magnesium bicarbonate molecule.

Anyway, it didn't turn out so bad in the end. Once in the ocean, the other carbon in my molecule took off with some hydrogens that wanted to party, leaving me behind with the magnesium. We crystallised out and settled on the ocean floor as part of a rock called dolomite. All was peaceful for a few million years.



I thought I might stay there forever, but it wasn't to be. The ocean floor I was on was near a subduction zone. Plate tectonic motion pulled us along and I got subducted! Carried down into the mantle! The increasing heat caused more and more chemical reactions until, about 150 km down, I had to let go of my magnesium buddy and (together with my oxygen mates) wound up squeezed into the mantle along with a whole lot of water molecules as

dissolved carbon dioxide and water. This was bad news for the mantle! Some of it melted, to form a type of magma called andesite. I was dissolved in this molten andesite, which was lighter than the surrounding mantle so started to force its way to the surface.

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Once we got near the surface the drop in pressure was very noticeable. Without the big squeeze on, my water mates and I didn't feel like being dissolved any more. Instead, we started to form bubbles, like those in a bottle of Coke when you take the lid off. Ever dropped a Mentos into Coke? Basically, that's what happened. All the molten rock spurted out of the surface as a volcano. I was super hot, and carried some pulverised rock high up into the atmosphere. The rock fell back down as ash, but I was back in the atmosphere where I had been about 70 million years earlier.

I hung around in the atmosphere for a few thousand years, then once again I dissolved in a raindrop, and this time fell into the ocean. I swam around for a few million years, but this time I got hooked up with some calcium in a thing called a stromatolite. Before I knew what was happening, I was part of a reef. It didn't stop there. My reef was buried under some siltstone, and then pushed up onto one of the newly forming continents as limestone.



Life was quiet for quite a long long time. By the time weathering and erosion exposed me again, the Earth was a very different place. It was a time called the Cambrian. The oceans were full of swimmy things, and a life was getting just underway on land. I was dissolved again and wound up in the ocean. This time though, I wound up part of a seaweed growing in the tidal zone. Some starfish thing came along and ate me, then this really scary fish thing ate the starfish. Respiration in the fish let me out into the ocean again, until another seaweed took me up. I kept going around like this for about twenty million years.

Finally, I evaporated and became part of the atmospheric carbon dioxide again. Out in the Sun again, dry for a change. However, it turned out that the cycle of photosynthesis and respiration takes place on land as well. I spent a year or so as part of a leaf of this fern thing, and then got eaten by some sort of insect which in turn was eaten by a froggy thing. The frog died before it had a chance to get eaten, but decay has much the same effect as the rest of the food chain and I spent a brief time in the atmosphere again.

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This was a time called the Carboniferous. Plants had gone mad - they were everywhere. The amount of oxygen in the atmosphere was nearly twice what it is today. I had gone back into the atmosphere as a methane, but that lasted hardly any time at all. Assaulted by two aggressive oxygens, I soon became carbon dioxide then was photosynthesised by this huge tree fern in a swamp. This time was a bit different, though. I wound up part of the

bark, in a molecule called lignin which doesn't break down easily. That was important. When my tree fern died, it fell into a swamp and was buried. I was on my way to becoming coal.

Life was quiet and dark as part of a coal measure for about a hundred million years. However, my coal seam was uplifted in a period of mountain building, and soon I was exposed to the atmosphere again. With all those aggro oxygens around, I couldn't last long. Sure enough,

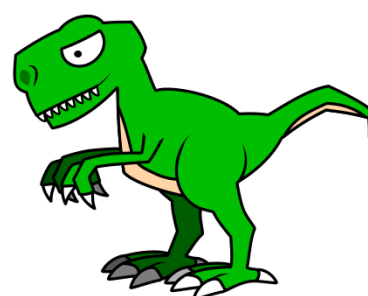


I was soon back in the air again as part of a carbon dioxide molecule.

I was captured by a fern again and then got eaten by Gigantosaurus. Wow! Here was my chance to be part of one of the biggest living things ever to walk the planet! However, this turned out not to be. Gigantosaurus digestive systems are very inefficient - I got pooped out. Talk about pride comes before a fall. I got eaten by a *dung beetle*. Gross!

Anyway, my dung beetle got its just desserts - it was eaten by some sort of small dinosaur. Once again, I was

passed back into the atmosphere by respiration and taken up by a plant. This time I was returned to the atmosphere in a forest fire - at least it was a change. I kept going around in the cycle of photosynthesis and respiration, becoming part of (I think) a moss, a snail, some sort of ancestor to asparagus, a bird-like dinosaur of some description and all sorts of things. It was a lively time, and I can't remember all the details. Sometime in the Jurassic I wound up in the ocean again, eventually becoming part of a fish. The fish was eaten by a pterosaur, which returned me to the atmospheric system. During the following few million years I got to try out being all sorts of molecules - simple sugars, fats, proteins and so on.



Right at the end of the Cretaceous I was hanging around as a fern again when I got eaten by a stegosaurus. This was one unlucky animal. It was sick, and couldn't keep up with the herd. It got attacked by a *Trex*! I wound up as part of the meanest animal ever! Unfortunately, T rexes are really aggro animals. My one got in a fight with another, and was killed. The other rex ate some of my rex, but not me. Instead, I got scavenged by a small furry thing - a mammal. I didn't know it at the time, but mammals were the coming thing. Nearly didn't make it though.

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You see, 65 million years ago this big as comet hit the Earth square on. It hit in shallow water in what is now Mexico. I had been around the food chain a few times by then and was doing time as part of a barnacle in what would eventually become Malaysia - a long way away. Didn't do me much good (or at least the barnacle), though. The impact sent so much dust and stuff into the atmosphere that the whole Earth was plunged into darkness. It got *cold*. My barnacle died. So did a whole lot of other

things - every animal over 10kg for starters, except for a few crocodiles. However, I was part of the shell of the barnacle. Even though I was dead, I was stuck to my rock. The acid rain after the impact dissolved the shell and I was washed into the sea again.

The oceanic food chain was badly disrupted by the impact as well, so I spent a lot of time dissolved in the ocean. Eventually, plankton photosynthesis was back up to a healthy level again. I became part of a small phytoplankton, which was eaten by a shrimp. Round and round I went, until one day my host fish died and settled to the bottom of the sea where it was buried.

Various chemical reactions took place and I wound up as part of a substance called keragen. This is oily stuff mixed up with a rock called shale. As I got buried deeper, I was squeezed out and was trapped in an oil and gas reservoir.

I might still be there if humans didn't have such a fondness for oil. Fifty years ago, my reservoir was discovered (actually, it is mostly gas) in Taranaki. Someone drilled into it, and WHOOSH! I was sucked up to the surface. They separated the oily stuff (called condensate) off from the gas and I got shipped up to Marsden Point to be refined. I wound up in some diesel, and was turned back into carbon dioxide in a farm tractor somewhere in Southland.

From there to you wasn't a big jump, actually. Once in the atmosphere again, I fairly quickly dissolved in the ocean east of New Zealand. I was absorbed by another plant plankton, eaten by little shrimp thing and that in turn was eaten by a fish.

The fish - hoki - was caught by a factory ship and quickly turned frozen fillets. That's how I got to you - coated in crumbs in a McDonald's Fillet of Fish ten weeks ago. Of course, I won't be part of you for long. The cell in your skin I'm part of will die, fall



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and probably be eaten by a dust mite. If I'm lucky, I might get respired out again and wind up part of the great cycle of life again. Otherwise, I'll get sucked into your vacuum cleaner and wind up in a landfill somewhere. Oh well, at least it will be quiet.

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